3° C., and a mean value 1,660° C. is considered to be accurate within ± 10° C., which is the estimated accuracy of the pyrometer.

To commemorate the centenary of the date when Kew Observatory first undertook the accurate calibration of barometers, the Laboratory had arranged a small exhibition of historical records and apparatus in the hall of Bushy House. The exhibits included two standard barometers of 1854 and 1858; when it was formed in 1900, the Laboratory took over with the Kew Observatory much of the work on the standardization of instruments which until then had been the responsibility of the Observatory.

NEW MAGNETIC MATERIALS OF HIGH COERCIVITY

By Prof. L. F. BATES, F.R.S.

DURING the past five to ten years, considerable strides have been made in our understanding of the theory underlying the production of materials of high coercivity. According to the domain concept of ferromagnetism[1], we picture a ferromagnetic metal as made up of a very large number of small regions or domains. Each of these is magnetized, more or less to the complete degree of saturation appropriate to the temperature of the material, with the direction of magnetization parallel to one of the directions of easy magnetization, these being the edges of the crystal cube in the case of iron. We think that the initial permeability of a material is determined by the ease with which boundary movements between adjacent domains can take place, so that any domain in which the direction of magnetization is more nearly aligned with respect to an applied magnetic field may grow in volume, at the expense of neighbours the magnetizations of which are less well aligned, simply by boundary displacement.

But let us suppose we are dealing with particles which are so small that they are, in effect, single domain particles with no domain boundaries inside them. It then follows that it may be difficult to change the direction of magnetization of such a particle, particularly if it possesses marked magnetic anisotropy, that is, if a crystal of the substance is much more easily magnetized along certain directions than along others—or if the particle is of a special shape, so that large demagnetization fields may arise if it is magnetized along certain axes of shape. Consequently, it should be possible to prepare permanent magnets from materials which formerly were regarded as quite unsuitable for such purposes, such as pure iron. At the Physical Society Exhibition this year, the Salford Electrical Co., Ltd., exhibited 'Gecalloy Micropowder Magnets' made from finely powdered iron. The powder is given an insulating coating and mixed in a conventional dough mixer with heat supplied from below. It is then prepared in a variety of shapes by the use of special press tools and powder presses. The new products are important because of their lightness—since they are about half as dense as ordinary permanent magnets—and because of their insulating properties. Incidentally, soft iron pole pieces are sintered as an integral unit with sintered alcomax alloys ('Sincomax') by Messrs. Murex, Ltd., who thus make many sintered permanent magnets of intricate shape.

The behaviour of permanent magnets made of 'Alnico' has been explained by Stoner and Wohlfarth[2] on the assumption that the material consists of finely divided particles, shaped as prolate spheroids, embedded in a weakly magnetic matrix. Now, we know that such iron – nickel – cobalt – aluminium – copper alloys are given exceptionally valuable properties by exposing them to a magnetic field while they are being cooled from a high temperature. The permanent magnetization parallel to the direction of the applied field is, of course, obtained at the expense of the permanent magnetization perpendicular thereto. We also know that if we take a single hexagonal crystal of cobalt it is comparatively easy to magnetize the crystal parallel to its axis, while it is much more difficult to magnetize it in the basal plane. Hence, the possibility arises of producing important magnetic materials which may be easily magnetized in one direction, if we can arrange that the axes of the constituent crystals are aligned in a preferred direction.

This problem has been tackled in two ways. Thus, Swift Levick and Sons, Ltd., have produced the commercially available 'Columax', which is an improved grade of 'Alcomax III', in which the equiaxed crystals of the normal alloy are replaced by long columnar crystals in a preferred direction parallel to the direction of magnetization determined during heat treatment in an applied field. The new magnets must always be in the form of simple solid cylinders or rectangular blocks, and cannot be provided with cored or drilled holes; but, of course, this does not preclude their use in many assemblies and iron circuits. Their maximum remanence is about 13,000 gauss and their coercivity between 700 and 740 oersteds. The quantity $(BH)_{\text{max.}}$, which is a criterion of suitability as a permanent magnet material, is of the order $6 \cdot 8 \times 10^6$ gauss-oersteds.

A second way consists in making magnets of compressed manganese bismuthide powder[3] (MnBi). Single crystals of manganese bismuthide are hexagonal and have properties resembling those of hexagonal cobalt, but the material has very high magnetic anisotropy and so possesses a very high coercivity; in fact, values of coercivity measured from an I,H curve as high as 12,000 oersteds have been recorded, which would mean that the coercivity as measured from a B,H curve, as normally specified by a manufacturer of permanent magnets, might be of the order of 7,000 oersteds. It would be surprising, however, if stable permanent magnets of a material as brittle as manganese bismuthide, with a Curie point around 350° C., could be prepared as conveniently as those described earlier.

In addition to the above materials, we also have on the market a material of high coercivity which is virtually a Heusler alloy in which the copper in the well-known aluminium–copper–manganese alloy is replaced by silver. Another important new development[4] in powder metallurgy is the production of the materials known under the trade name of 'Ferroxdure', which consist of blocks of compressed oxides of iron and barium. These have coercivities of the order 1,450 oersteds with a value of $(BH)_{\text{max.}}$ of about $0 \cdot 85 \times 10^6$ gauss-oersteds.

Naturally, all such materials are of considerable interest because of the special uses to which they may be put by persons of ingenuity.

[1] Bates, L. F., "Modern Magnetism", 443 (Cambridge, 1951).
[2] Stoner, E. C., and Wohlfarth, E. P., *Phil. Trans. Roy. Soc.*, A, **240**, 599 (1948).
[3] Adam, E., *Rev. Mod. Phys.*, **25**, 306 (1953).
[4] Went, J. J., *et al.*, *Philips Tech. Rev.*, **13**, 194 (1952).